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Abstract of the national paper of Bulgaria

Space activities in Bulgaria from 1982 to 1999

1. During the period 1982-1999, scientific programmes and the relevant equipment for the space flight of the second Bulgarian astronaut were prepared and successfully deployed on board the manned space station Mir. Bulgarian scientists also took part in international projects and programmes such as Vega, Phobos-1 and 2, Interball, Koronas, Aktiven, the Mir space station and Priroda.

2. Space studies concentrated on scientific and applied research in a number of major fields.

1. The Space-Earth system

3. The following main results were obtained in the field of Earth observation (remote sensing):

(a) Instrumentation and complexes such as the multi-channel spectrometer complexes Spectrum-15 (on the Salyut-6 manned orbital station); Spectrum-15M (on the Salyut-7 manned orbital station); SMP-32 (on board the Meteor-Priroda satellite as part of the Bulgaria 1300-II space project)); Spectrum -256 (on the Mir space station); and ISOCH-20 and ISOCH-111; and the R-400 two-polarization scanning radiometer complex (on board the "Priroda module docked with Mir) were designed to carry out remote sensing of Earth and the planets;

(b) New results concerning the interaction of incidental radiation with different natural formations, their status and the irradiance and spectral reflectance structure were obtained. Formulas for spectral reflectance coefficients, spectral reflectance characteristics, reflectance indices, vegetation coefficients and colour coordinates of mixed spectral classes of natural formation were obtained, including the general case of N classes. The theoretical statistical distributions of the most frequently used vegetation coefficients were also obtained;

(c) Techniques and instrumentation for the study of the impact of heavy metals, high fertilization, water and herbicide stress, ultraviolet radiation and drought on soil and vegetation were developed and implemented;

(d) Bulgarian scientists participated fruitfully in the following United Nations and European Union projects: Coordination of Information on the Environment (CORINE) Land Cover and MARS and Environmental Related Applications (MERA). Results were obtained

by means of interpretation of space images for purposes of agriculture, geology, hydrology, study of global change and so on;

(e) Bulgarian scientists took part in the Phobos scientific project to examine the surface of Mars and Phobos: the Fregat video spectrometer and navigational complex was designed under the leadership of Bulgarian scientists, together with scientists of Germany and the Russian Federation; data acquisition, processing and interpretation of the multi-channel images was performed together with scientists of Finland, France, Germany, the Russian Federation and the United States of America; the results have been published in *Nature*, *Planetary and Space Science* and other journals.

4. As regards the use of satellite data in weather forecasting, after the beginning of the reception of data from Meteosat in Bulgaria in 1987, the priorities of satellite meteorology research were directed mostly to the use of Meteosat data in weather forecasting over the Mediterranean. Over the last years, the scientific research in this field has focused on the use of Meteosat data in the 6.3 μm water vapour channel for analysis and forecasting of different types of Mediterranean cyclone that affect the weather over the Balkans. As a result, indicators of water vapour images that are informative about the evolution of such cyclonic systems have been obtained.

5. Another field of space research was the qualitative and quantitative relationship between Meteosat data and the potential vorticity (PV) field. The correlation of Meteosat data to the high values of PV (PV anomalies) associated with cyclonic developments in the middle of the troposphere was studied.

6. The latitudinal effects on the relationship between water vapour channel data and the PV at 500 hPa have also been studied. Linear regression models were fitted to the samples from a Mediterranean case study in the northern (35°-55° N) and southern (25°-35° N) belts. Finally the potential for validating numerical weather prediction output by comparing WV imagery with PV fields has begun to be studied.

2. Space physics

7. The scientific instrumentation for the Council on International Cooperation in the Study and Utilization of Outer Space (INTERCOSMOS)/Bulgaria-1300-1 satellite was developed and launched successfully in 1981. The scientific programme for it was directed at magnetosphere-thermosphere-ionosphere interactions on a planetary scale. Fluxes of charged particles, magnetic and electric fields and currents, electron and ion densities, plasma waves and irregularities, electron, ion and neutron temperatures and so on were measured on board and analysed during both calm and turbulent periods in solar-terrestrial relationships.

8. As regards theoretical research, in magnetosphere physics a study was carried out on field-aligned currents in extraterrestrial space, relating to both the magnetosphere and the ionosphere. Studies in the field of ionosphere physics were conducted in the following areas:

(a) Upper ionosphere: creation of prediction methods for critical frequencies of the F-region;

(b) Middle and lower ionosphere: development of models of the interaction between cosmic rays and high-energy particles, the D- and E-regions and the middle atmosphere;

(c) Irregularities in the ionosphere and their dynamics;

(d) Investigation of periods of particular solar activity, with proton flares and coronal mass ejection events associated with geomagnetic and ionosphere storms. Here parallel data from the INTERCOSMOS Bulgaria-1300, Dynamics Explorer - 1 and 2 and Arcad satellites were used. In physics of the middle atmosphere (strato-mesosphere) research centred on the

behaviour of the minor constituents in the middle atmosphere, ozone, carbonic oxide and others, which are of ecological importance.

9. Scientists from the Bulgarian Academy of Sciences, together with scientists from the Institute for Medical and Biological Problems in Moscow and the Belgian Institute for Space Acronomy, conducted a long-term investigation of the radiation environment of the Mir space station with the Bulgarian-Russian active space dosimeter complex Liulin. An empirical model was built and can be used for prediction of the expected doses and fluxes on the orbit of the International Space Station.

3. Satellite communications

10. The existing system for space communications based on board satellites of the Statzionar type at 14° W was developed further. A five-year research project under Bulgarian climatic conditions was carried out by means of specially designed relay systems in order to estimate the impact of the radio wavelength propagation in the range of frequencies greater than 10 GHz. Satellite transmitters working in the 11, 20 and 30 GHz bands were designed and launched on board a satellite in order to study the propagation of wavelengths in those frequency ranges. The ground-based receiver of the International Telecommunications Satellite Organization was established, working in the frequency range 5.9-6.4 GHz. The emission of Bulgarian National Television's "TV-Bulgaria" programme started through the European Telecommunications Satellite Organization satellite at 13° E.

4. Space life sciences

11. Research was carried out on the following topics in the field of space medicine and biology:

(a) The impact of immobilization on the central nervous system and the general functional state of the human organism;

(b) The status of the muscle system in space conditions;

(c) How factors such as age and professional training affect reaction to high-load conditions;

(d) Psychological reactions of astronauts to microgravity conditions and peculiarities of the wake-sleep cycle. Bulgarian devices and systems for psychodiagnostics in space conditions were designed, developed and successfully used.

12. New types of space foods have been created and technologies for their production have been developed.

13. Improved Svet greenhouse models were tested on board Mir together with Russian and United States astronauts, and the first plants were grown within one vegetation cycle.

14. Scientists from the Bulgarian Academy of Sciences are now working on the development, testing and calibration of a new-generation active space dosimeter complex of the Liulin-4 type. It consists of four mobile dosimetry units and one control and interface unit. The system's main purpose is to monitor simultaneously the doses and fluxes at four independent places on the United States Laboratory module of the International Space Station. The system is scheduled for launching during the first half of 2000.

15. The Neurolab system for psycho-physiological measurements was tested in space conditions.

5. Satellite techniques and technologies

16. It is a characteristic of the Bulgarian space programme that implementation has been completed not only of complex devices and systems for space research, but also of space technologies for new materials and products developed by Bulgarian scientists. Analysis and application of multi-channel data and images were also implemented. This refers first of all to the complex scientific techniques and equipment developed for the space flights of the first and second Bulgarian astronauts, the satellites included in the Bulgaria-1300 space project and the Bulgarian scientific space complexes in the framework of the Vega, Interball, Phobos, Priroda and other international missions.